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# Acorn Pocket Book Plotter User Guide

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Plotter is a graphical plotting application for the Acorn Pocket Book. You can use it for plotting

- Cartesian functions
- polar functions
- parametric functions
- inequality graphs
- families of functions
- coordinate pairs.

Use Plotter to help tackle your mathematical problems. By taking a graphical approach, rather than simply writing out and solving equations, you get much more of a feel for a problem. This can often lead intuitively to alternative solutions.

As well as just plotting graphs of functions, Plotter can

- trace functions
- recalculate functions dynamically for a given range
- zoom in and out of any section of a graph
- save, load and merge graphs.

## Conventions – choosing menu options

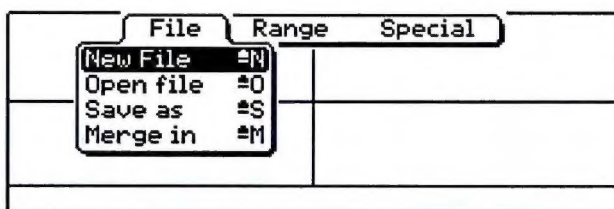
When you press the Menu key, the menu you see will depend on what you're doing with the Pocket Book at the time. Throughout this guide, we'll use the following convention:

### What the guide says:

Press the Menu key and choose **File/New file**.

### What you do:

- 1 Press the Menu key to bring up the menu screen.
- 2 Use the left and right arrows to display the **File** menu.
- 3 Use the up and down arrows to highlight the **New file** option, and press Enter.



**Note:** Once you get used to choosing menu options, you can start using keyboard short-cuts instead. For example, pressing Acorn-N would have the same effect as pressing Menu and choosing **File/New file**.

## Installing Plotter

Plotter is supplied on a Solid State Disk (SSD).

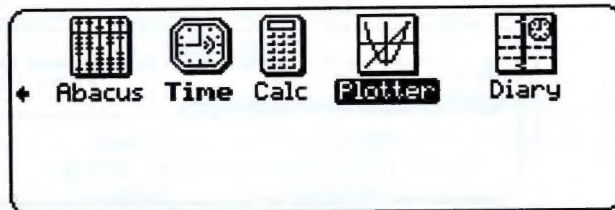
- 4 Insert the SSD into drive A or B in your Pocket Book.
- 5 From the Desktop screen on your Pocket Book, press the Menu key and choose **Apps/Install application**:



- 6 Select the drive (A or B) containing the Plotter application.
- 7 Use the file selector to display **Plotter.app** on the first line of the dialogue box (if you're not sure how to do this, see the *Acorn Pocket Book User Guide*).



- 8 Choose the position where you want your application to appear (current or last) and press Enter. The desktop display should now show the Plotter application:



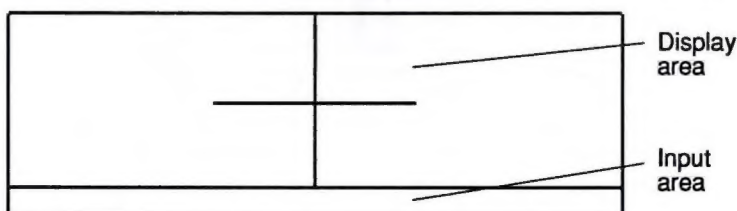
For more detailed instructions on installing applications, see the user guide supplied with the *Acorn Pocket Book User Guide*.

## Plotter basics

This section tells you how to start and quit the Plotter application, how to toggle between Wide and Narrow modes, how to plot simple functions and how to turn off the x-y axis display.

### Starting Plotter

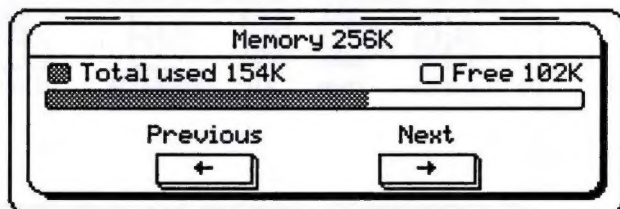
To start Plotter from the desktop screen, move the cursor over the Plotter application icon and press Enter. You'll see a blank display:



**Display area** – This is where your functions are plotted. By default, it shows the x and y axes, over the range -1 to +1 (known as Narrow mode – see *Narrow and Wide modes* on page 5).

**Input area** – This is where you enter the mathematical expressions describing the functions you want to plot (you'll see the cursor flashing in the bottom lefthand corner). You can edit the text of a function using the arrow keys, the Acorn key and the Delete key. When you type in a function and press Enter, the function is plotted.

**Note:** If you see the message *No system memory* when you try to start Plotter, press Acorn-M from the desktop screen to see how much free memory you've got (you need at least 45K).

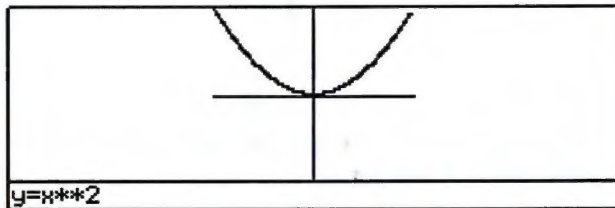


If you've got less than 45K free, you'll need to quit an application (or delete some unwanted files) to free up some memory. See your *Acorn Pocket Book User Guide* for more on this.

## Plotting two simple graphs

As an introduction, here's how to plot two simple graphs:

- 1 Enter  $y=x**2$  (i.e.  $y=x^2$ ) into the Input area (you can include spaces in your functions, if you want, e.g.  $y = x**2$ ).
- 2 Press Enter. The graph will appear in the Display area:



If you want, you can now enter a new function. Its graph will be plotted together with the first function:

- 1 Move the cursor to the end of the Input area and edit the function to read  $y=1/x$ .
- 2 Press Enter.

Notice that when the "Plotting" message stops flashing on the screen, your second graph does not seem to appear in the Display area. Don't worry, it's not a mistake! It's because the function  $y=1/x$  only has values that lie outside Plotter's default display range.

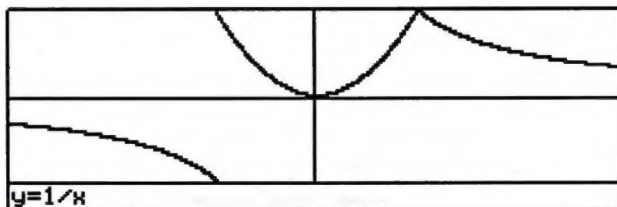
There are a number of ways in which you can alter the display range. The next section (*Narrow and Wide modes*) shows you one way of seeing your second graph. *Changing the Display range* on page 17 tells you all the other methods.

## Narrow and Wide modes

By default, Plotter starts up in Narrow mode (as shown above). This is handy when you want to preview a graph, or draw graphs quickly, as only the central portion of the display is used.

To see more of a graph, you can use Wide mode, which uses the whole screen. For clarity, all the examples in this Guide are shown in Wide mode. For speed, you'd normally use Narrow mode.

Change from Narrow mode to Wide mode by choosing **Special/Wide** (or pressing Acorn-W). You'll now be able to see the second of your two functions from the previous section:

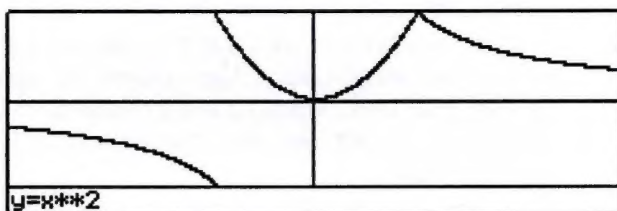


To change back to Narrow mode again, choose **Special/Narrow** (or press Acorn-W again).

### Scrolling through equations

Once more than one function is displayed, you can use the up and down arrows to cycle between equations in the Input area.

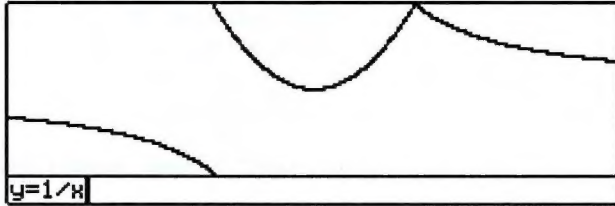
Press the up arrow key to display the previous equation:



This is very useful if you want to plot similar functions, or when you're tracing a function (see *Tracing functions* on page 23).

## Displaying and removing the axes

By default, the x and y axes are shown in the Display area. You can turn them off by choosing **Special/Remove axes** (or pressing Acorn-A):



Note that removing the axes will cause all graphs to be re-plotted. You can re-display the axes at any time by pressing Acorn-A.

## Deleting a graph (or point) from a Plotter file

You can remove a graph or point from the current Plotter file.

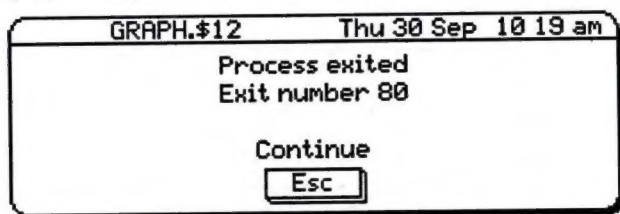
To do this:

- 1 Use the up and down arrow keys to display the function or point in the Input area.
- 2 Choose **Special/Delete** (or press Acorn-E).  
The current file will be redrawn to display all graphs except the one you've deleted.

You can delete a graph even while its being plotted by pressing Acorn-E.

## If Plotter runs out of memory

If Plotter tries to plot a graph and runs out of memory half way through, you might see the following error message:



You'll need to quit an application or delete some unwanted files to free up some memory. See your *Acorn Pocket Book User Guide* for more on this.

## Quitting Plotter

When you decide you want to stop using Plotter, choose **Special/Exit** (or press Acorn-X). The current Plotter file will be saved and the display will return to the Pocket Book desktop. For more on Plotter files, see page 26.

## What next?

You've just had a very brief introduction to using Plotter. The next few sections explain in detail how to plot different types of graph, plot multiple graphs, change the display area, trace functions and manipulate Plotter files.

When you're familiar with Plotter, work through the example in *Using Plotter to solve a problem* on page 29.

## Plotting different graph types

This section describes the types of graph that Plotter can draw.

You can make the expression (e.g.  $f(x)$ ) on the righthand side of an equation as complicated as you like, as long as you bear a few things in mind. *Operators and functions* on page 32 lists all the operators (such as \* (multiply)) and functions (such as  $\sin(x)$ ) that you can include in an expression. *Operator precedence* on page 33 explains the order in which operators and functions are evaluated.

**Note:** If at any stage you see either of the error messages *Disc full* or *No system memory*, you'll need to make some space on your Pocket book's internal disk. Press the Desktop button and either quit an application or delete some unwanted files. See your *Acorn Pocket Book User Guide* for more information on this.

### Cartesian functions

A Cartesian function (of the form  $y=f(x)$ ) defines the distance  $y$  of a point from the  $x$  axis as a function of its distance  $x$  from the  $y$  axis. You've already plotted two Cartesian functions in *Plotter basics* on page 4. The variable name in Cartesian functions is always  $x$ .

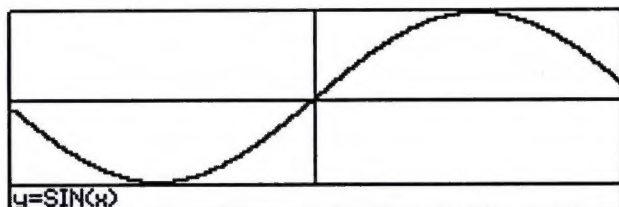
Before you plot another function, open a new Plotter file (there's more about Plotter files on page 25):

- 1 Press Acorn-N.
- 2 Type in a name for your new file (e.g. Plot1).
- 3 Press Enter. You'll see a blank Plotter screen.
- 4 If you're not already in Wide mode, press Acorn-W.

Now plot the graph of  $y=\sin(x)$ :

- 1 Choose **Special/Radians** (or press Acorn-D) so you're plotting in radians instead of the default of degrees (there's more on this in *Degrees and radians* on page 24).

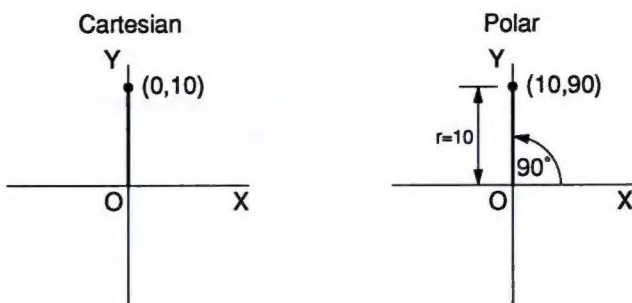
- 2 Type the function  $y=\sin x$  and press Enter. You'll see your graph plotted after a few seconds:



Notice that Plotter supplies the brackets automatically for you, and puts the function name (SIN) in upper case.

## Polar functions

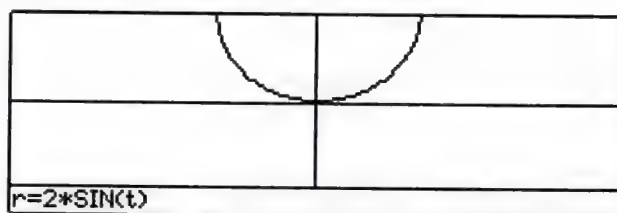
Plotter is capable of displaying polar functions (of the form  $r=f(t)$ ). A point's position is represented by its distance ( $r$ ) from the origin and an angle ( $t$ ) from the  $x$  axis. For example the point  $(0,10)$  in Cartesian coordinates is represented as  $(10,90)$  in polar coordinates:



Plotter can plot polar functions with  $r$  as a function of a single variable  $t$  (for theta).

For example, to plot the simple polar function  $r=2\sin(t)$ :

- 1 Start a new Plotter file – press Acorn-N, type in a file name (such as Plot2) and press Enter.  
(It's not actually necessary to start a new file. You can plot more than one type of graph in the same file – see *Plotting multiple graphs* on page 15.)
- 2 Type in  $r=2\sin(t)$  and press Enter.  
Your function will appear on the screen:



The range of  $t$  (theta) over which a polar function is plotted is set from  $0^\circ$  to  $360^\circ$  (0 to  $2\pi$  radians) by default. You can change both the default range for  $t$ , and whether  $t$  is in degrees or radians – see *Changing the plot ranges* on page 19 and *Degrees and radians* on page 24.

**Note 1:** Plotter automatically *deprecates* the multiplication sign (i.e. it understands that the multiplication sign is implied in the equation and adds it automatically). There's more on this in *Operators* on page 33.

**Note 2:** Notice that you can't see all of the graph on the screen at the moment (it's a circle). You'll find one way of solving this in *Changing the plot ranges* on page 19.

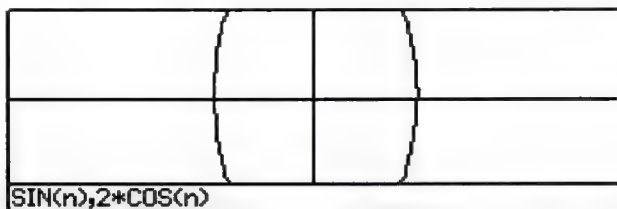
## Parametric functions

Sometimes it's easier to represent a function by expressing  $x$  and  $y$  separately in terms of a third independent variable,  $n$  (i.e.  $f(n), g(n)$ ). Any value given to  $n$  produces a pair of values (parametric values) for  $x$  and  $y$ . You can use Plotter to produce a graph of the form  $y=f(x)$  from a parametric equation, over a given range of values for  $n$ .

To plot a parametric function, enter the two functions ( $f(n)$  **first**) separated by a comma (,).

### Example 1

- 1 Press Acorn-N to start a new Plotter file.
- 2 Make sure you're in Radians mode (see *Degrees and radians* on page 24).
- 3 Type in the parametric function `sinn,2cosn` and press Enter:



By default, the range of  $n$  over which the  $x$  and  $y$  functions are evaluated is set between  $-4$  and  $4$ . The next example tells you how to change this. See also *Changing the plot ranges* on page 19.

Notice that you can't see the whole of the graph in this case. *Panning* on page 22 tells you how to pan the display to look at another part of the graph.

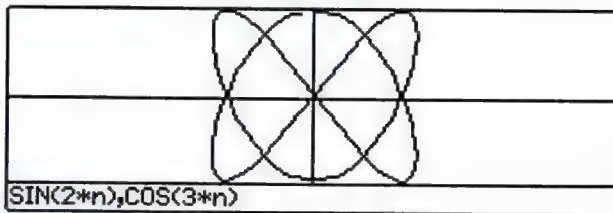
## Example 2

When you're plotting parametric functions, it's sensible to check the range of  $n$  being used first. *Example 1* above happened to use trigonometrical functions, so  $n$  was representing an angle. The default range for  $n$  is  $-4$  to  $+4$ , which is why the example worked in Radians mode. You could have got the same result in Degrees mode by changing the range of  $n$  to be 0 to 360. Here's another example, but with  $n$  in degrees:

- 1 Start a new plotter file.
- 2 Make sure you're in Degrees mode, and Wide mode.
- 3 Choose **Range/Other ranges** (or press Acorn-U) and change the range of  $n$  as below, then press Enter:

| Other ranges |     |
|--------------|-----|
| • n min      | 0   |
| • n max      | 360 |
| • t min      | 0   |
| • t max      | 360 |

- 4 Enter the function  $\sin 2n, \cos 3n$ . You'll see the following graph:



### Inequality graphs

You can use Plotter to solve inequalities. To plot an inequality, simply type it in the Input area. The area on the graph which satisfies the inequality appears shaded.

For example, here's the graph of  $y > 0.5$ :

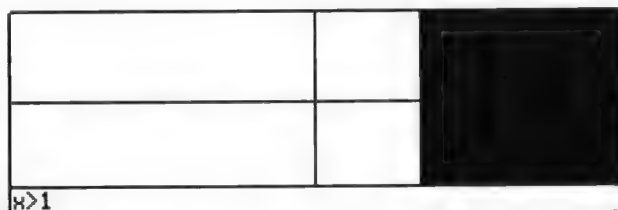


If there are any Cartesian, polar or parametric graphs already on the screen a warning is displayed, as you can't mix inequality graphs with other graph types or point data in the same file:



To continue, you'll have to create a new file (by pressing Acorn-N) to hold the inequality.

Inequalities can have either x or y as the variable. For example here's the graph of  $x > 1$ :



You can use Plotter to solve multiple inequalities. See *Multiple inequality graphs* on page 16.

## Plotting points (coordinate pairs)

As well as plotting complicated functions, you can plot single points. This is useful for plotting experimental data, for instance.

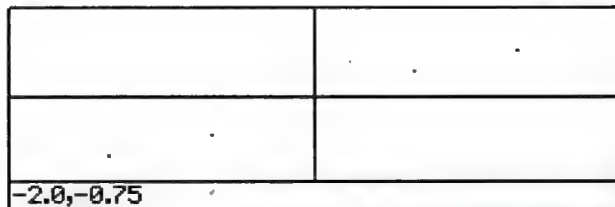
Simply type in the x and y coordinates of a point in the Input area, separated by a comma. The graph below shows the points

(-2.0,-0.75)

(-1.0,-0.5)

(1.0,0.25)

(2.0,0.5)



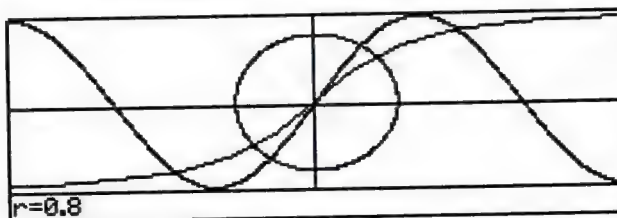
## Plotting multiple graphs

You can display more than one graph at a time in a Plotter file:

- You can plot multiple graphs of the same type (e.g. polar).
- You can plot graphs of different type.

You can mix Cartesian, polar and parametric graphs freely in the same graph file, as well as point data. The figure below shows three functions:

|                      |              |
|----------------------|--------------|
| $y=\sin(x)$          | (Cartesian)  |
| $r=0.8$              | (polar)      |
| $\sinh(n), \tanh(n)$ | (parametric) |



**Note:** You **can't** mix inequality graphs with other types of graph, but you **can** plot a graph that satisfies more than one inequality (see *Multiple inequality graphs* on page 16).

- You can plot families of graphs.

## Families of graphs

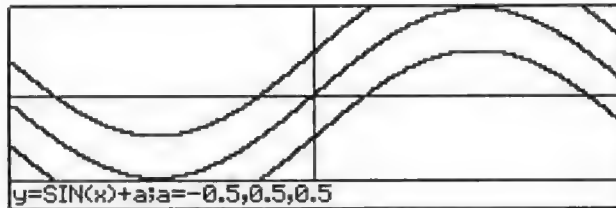
Plotter allows you to plot a family of graphs in one go by using a second variable,  $a$ . You simply type in the function followed by the range of values for  $a$ , separated by a semicolon (;).

For example, to plot the three graphs  $y=\sin(x)-0.5$ ,  $y=\sin(x)$  and  $y=\sin(x)+0.5$ :

- 1 Press Acorn-N to open a new Plotter file, in Radians mode.
- 2 Type  $y=\sin(x)+a$ ;  $a=-0.5, 0.5, 0.5$

The three numbers following the semicolon are the minimum value for  $a$ , the maximum value for  $a$ , and the step value for  $a$  respectively.

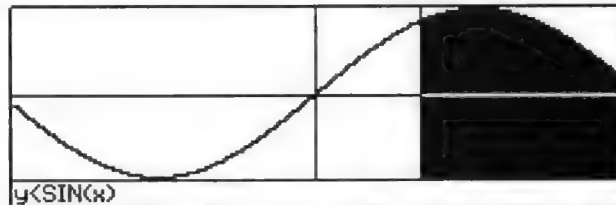
After a few seconds the three graphs will be plotted:



### Multiple inequality graphs

You can plot the area that satisfies more than one inequality. For example, to find the area that satisfies  $x > 1$  **and**  $y < \sin(x)$ :

- 1 Open a new Plotter file (use Radians mode).
- 2 Type  $x > 1$  and press Enter.
- 3 Edit the Input area to read  $y < \sin(x)$  and press Enter:



Now the shaded part of the display shows the area that satisfies both inequalities.

### Changing the Display area

There are various ways you can alter how much of a graph appears in the Display area. You can

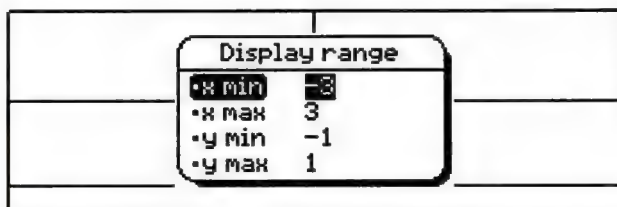
- change the ranges of the x and y axes
- change the default plot ranges used for n and t
- zoom in and out of the graph
- pan up, down, left or right.

## Changing the Display range

### Wide mode

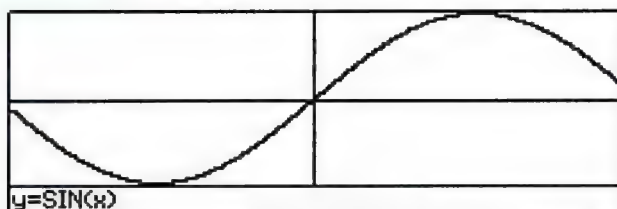
By default, in Wide mode the Display area shows the range  $-3$  to  $3$  on the x axis and  $-1$  to  $1$  on the y axis.

Use the **Range/Display range** option (or press Acorn-R) to change this:

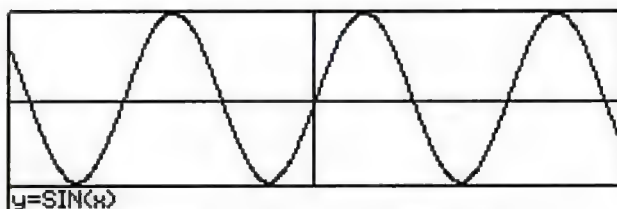


When you alter any of these maximum and minimum values, any functions in the current Plotter file are redisplayed to reflect the new range.

For example, using the default range of  $-3$  to  $3$  for the x axis and  $-1$  to  $1$  for the y axis, the function  $y=\sin(x)$  looks like this (using Radians mode):

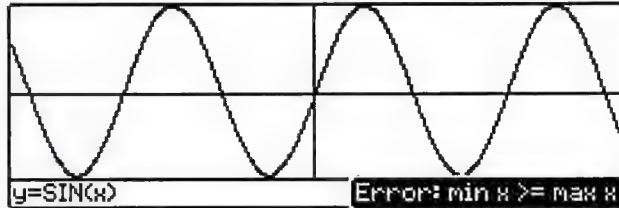


If you change x min to  $-10$  and x max to  $10$ , the Display area will look like this:



To see what the current range is set to, press Acorn-R (to leave the range unchanged, press Esc).

**Note:** If you try to set the range incorrectly, Plotter will display an error message, and use the previous values. For example, here's what happens if you try and set x min to 1 and x max to -1:



### Narrow mode

The Display range in Narrow mode depends on a number of factors:

- When you start a new Plotter file in Narrow mode, the default x range is -1 to 1.
- If you change from Wide display to Narrow mode, the x range is truncated (i.e. a range of -3 to 3 in Wide mode becomes -1 to 1 in Narrow mode, and part of your display is 'chopped off').
- If you're already in Narrow mode and you change the Display range, Plotter will fit the new range into the Narrow mode display.

If you then return to Wide mode, the x range will be increased by a factor of 3 to fill the whole screen.

**Note:** Sometimes you might not see the numbers you expect in the Display range menu. For example, if you start in Wide mode with a range of x from -10 to 10 and then change to Narrow mode, pressing Acorn-R will show an x range of 33333333 to 33333333 instead of -3.33333 to 3.333333.

## Changing the plot ranges

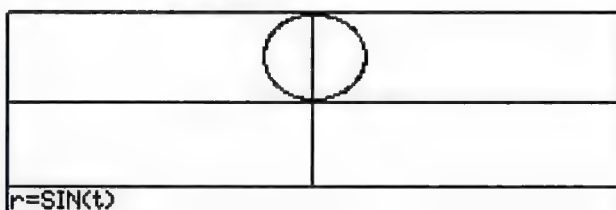
If you're plotting polar or parametric functions, you might want to change the range over which a function is plotted. In fact, it's always good practice to check the plot ranges before you start. To do this, choose the **Range/Other ranges** option (or press Acorn-U):

| Other ranges |     |
|--------------|-----|
| • n min      | -4  |
| • n max      | 4   |
| • t min      | 0   |
| • t max      | 360 |

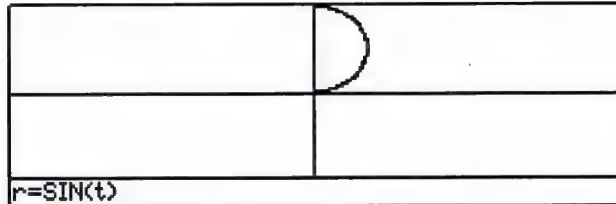
The ranges above show the default settings in Degrees mode. In Radians mode, t goes from 0 to 6.2831854 ( $2\pi$ ). Parametric functions use the variable n; polar functions use the variable t.

**Note:** If you're not careful, you might get confused when plotting parametric graphs that use trig functions (see *Example 2* on page 12) as n will represent an angle. Check the range of n carefully before you plot these types of functions.

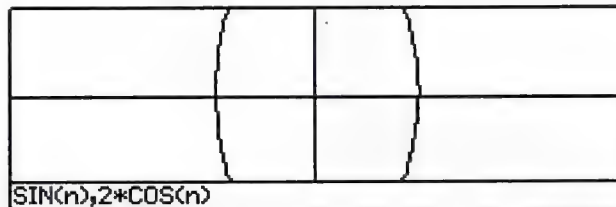
For example, here's the polar function  $r=\sin(t)$ , plotted over the default range for t of  $0^\circ$  to  $360^\circ$ :



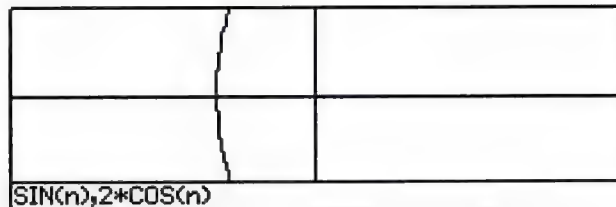
If you change the upper limit for  $t$  to  $90^\circ$ , you'll get the following graph:



Another example: here's the parametric function  $\sin(n), 2 \cdot \cos(n)$  in Radians mode with the default settings for  $n$ :



Here's the same function, plotted with  $n$  min =  $-4$  and  $n$  max =  $0$ :

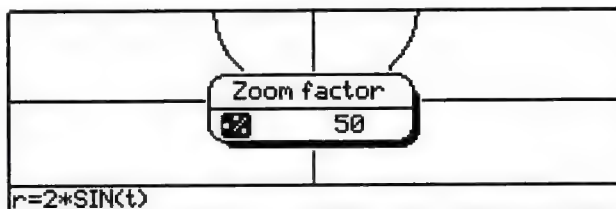


## Zooming

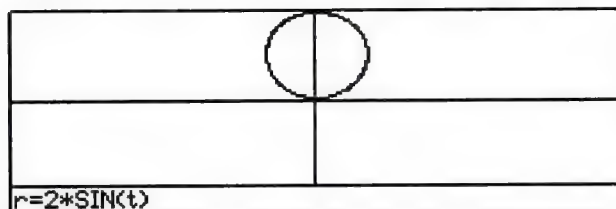
You can also change the Display range using the **Range/Zoom** option (or by pressing Acorn-Z). This allows you to enlarge or shrink the Display area, keeping the x/y aspect ratio constant. A zoom factor of 200% will enlarge displayed graphs by a factor of 2.

Here's how to see more of the function  $r=2*\sin(t)$ :

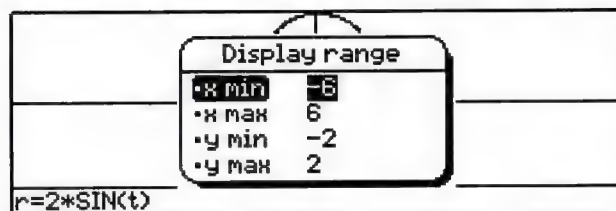
- 1 Choose **Range/Zoom** (or press Acorn-Z).
- 2 Set the zoom factor to 50%:



- 3 The graph will be scaled to 50% of it's original size:



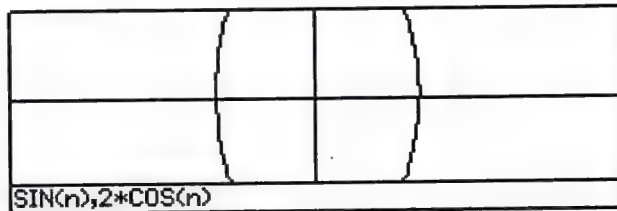
If you look at the display range by pressing Acorn-R, you'll see that as a result of this zoom, the xy axis ranges have been altered:



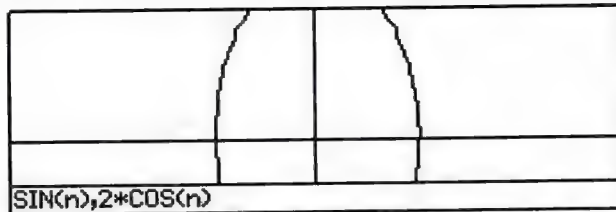
## Panning

Another way of changing the Display range is by panning. Choose **Range/Pan** (or press Acorn-P to enter Pan mode. This allows you to change the Display area by using the arrow keys.

Consider the function  $\sin(n), 2 \cdot \cos(n)$  (plotted with the default settings for  $n$ ):



- 1 Choose **Range/Pan** (or press Acorn-P) to enter Pan mode. You can now move around the Display area using the arrow keys.
- 2 Press the up-arrow once. The function will be redrawn to display part of the function higher up the y axis:



Each time you press an arrow key, the function is recalculated and redrawn.

- 3 Press Esc to exit Pan mode.

When you press an arrow key in Pan mode, the Display area is moved in the direction of the arrow key, by an amount equal to half the displayed range. For example, if the displayed range is  $-1$  to  $1$  on the x axis and  $-1$  to  $1$  on the y axis, and you press the left arrow key, the new range will be  $-2$  to  $0$  on the x axis and  $-1$  to  $1$  on the y axis. The size of the displayed area remains constant, but its position changes.

### Multiple pans

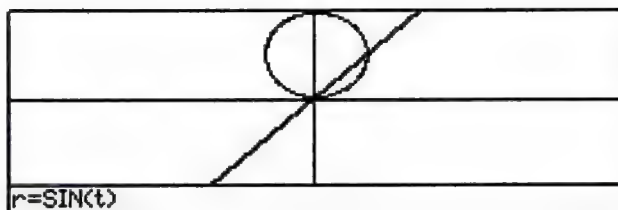
If you're in Pan mode and you want to pan by more than one step, you don't have to wait for all your functions to be redrawn before you can pan the second step. Simply press the appropriate arrow key, and the current plot will be interrupted, starting again at the new pan position. You can do this as many times as you like.

## Tracing functions

Plotter allows you to trace graphs using the cursor, and obtain the approximate function values at different points along the graph. You can only trace Cartesian, polar, and parametric functions.

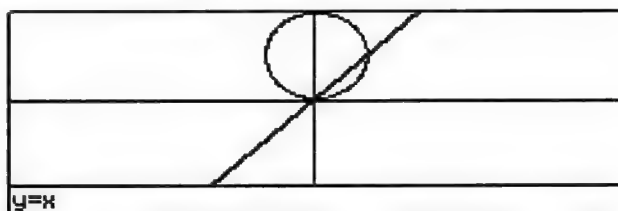
To enter Trace mode, first use the up and down arrow keys to display the function you want to trace in the Input area (this only applies if there's more than one function plotted). Then choose **Special/Trace** (or press Acorn-T).

For example, here's a Plotter file with the functions  $y=x$  and  $r=\sin(t)$  plotted:



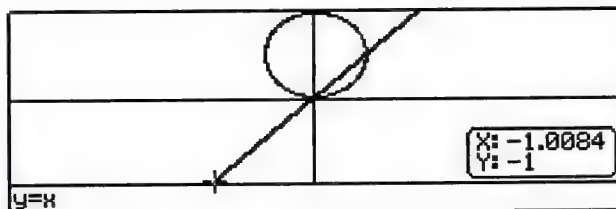
To trace the function  $y=x$ :

- 1 Press the up or down arrow keys until the function  $y=x$  is shown in the Input area.

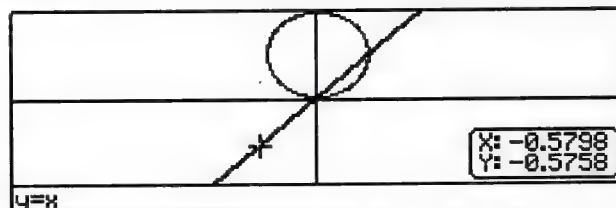


- 2 Press Acorn-T to enter Trace mode.

A cursor will appear on the graph near the left hand side of the graph display. The coordinates for the cursor are also displayed in a small window at the bottom right of the Display area.



- 3 Use the left and right arrows to move the cursor along the graph. The cursor will automatically move up and down to stay on the graph, and the cursor coordinate display will be updated to show the new cursor position. This enables you to obtain the approximate values for the function at different points along the graph:



- 4 To exit Trace mode, press Esc.

Trace mode reports the dependent and independent variables (x and y, or r and t) depending on the graph type.

## Degrees and radians

By default, the Plotter application uses degrees for any trigonometric calculations. You can change this by choosing **Special/Use radians** (or by pressing Acorn-D). This will cause Plotter to re-display all the currently displayed graphs, using radians. You'll also see a message flashed briefly on the display, saying *Now using radians*. To return to using degrees, choose **Special/Use degrees** (or press Acorn-D again).

You can toggle between degrees and radians at any time. You'll usually want to choose Degrees or Radians mode when you open a new Plotter file, before you enter any functions.

### Checking which mode you're in

If you're not sure whether you're in Degrees or Radians mode, press the Menu button and look at the Special menu. If the Special menu says *Use degrees*, that's the mode you would change to by choosing the menu option (so, you're currently in Radians mode!).

## Interrupting a plot

You don't have to wait for a graph to finish plotting before you can do something else in the current Plotter file. While a graph is being drawn, you can do any (or all!) of the following:

- Delete the current function (i.e. stop it plotting):  
Press Acorn-E.
- Delete another function:  
Press the up (or down) arrow until the function you want to delete is in the Input area, then press Acorn-E.
- Edit any of the functions in the current Plotter file:  
Press the up (or down) arrow until the function you want to edit is in the Input area. Edit that function and press Enter.  
**Note:** This adds another function to your list, it doesn't delete the one you've edited.

- Perform multiple pan operations in Pan mode:  
While you're in Pan mode, press any of the arrow keys as many times as you want to achieve the required pan.
- Choose any menu option (or short-cut).  
For example, you can toggle between Wide and Narrow modes, change the Display range, zoom or remove the axes.

**Note:** Each time you press a key during a plot or pan, the current plot stops and the whole file starts to redraw from scratch. This doesn't normally cause problems, but if you perform complicated edits to more than one function, it can take a while before Plotter 'catches up' with the changes you've made and redraws the screen for the last time!

## Plotter files

Like most other Pocket Book applications, Plotter is in fact an editor for a specific type of file. The files edited by Plotter contain functions and graphs, just like the files edited by Write contain text, and the files edited by Abacus contain spreadsheets.

Every time you enter a function, it is added to the file, just as a new record in Cards is added to the database.

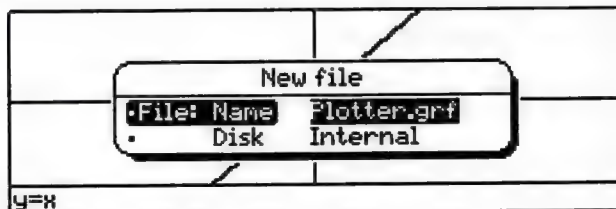
You can create several files with different graphs in them and store them for future reference, just as you would with any other editor.

### Creating a new Plotter file

To create a new file:

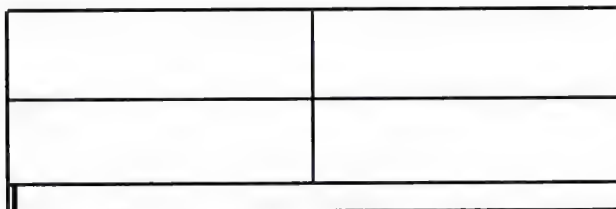
- 1 Choose **File/New file** (or press Acorn-N).

A standard Pocket Book New file dialogue box is displayed:



- 2 Type in the name for the new file (`Plotter.grf` is the default) and press Enter.

The new file is created, and the screen is cleared to show that there are no graphs in the current file.

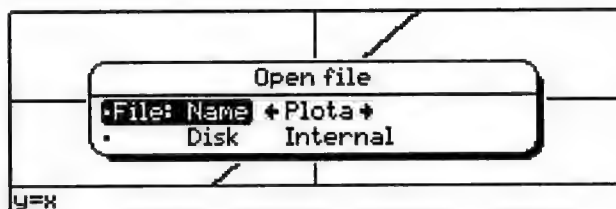


**Note:** Plotter files have the suffix `.grf`. If you don't supply it when you create a new file, it will be added automatically.

## Loading an existing Plotter file

To load a Plotter file from within the Plotter application:

- 1 Choose **File/Open** (or press Acorn-O). A standard Pocket Book file dialogue box is displayed, allowing you to select the file to be opened:



- 2 Use the left and right arrow keys to choose the file you want to open (you can press Tab to display the whole list of available files) and press Enter.

When you press Enter, the file is loaded, and any graphs in it are displayed, replacing the graphs in the current file.

## Saving and merging Plotter files

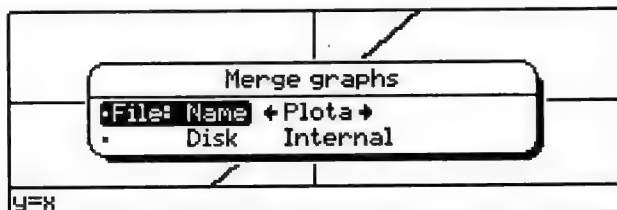
When you quit an existing Plotter file (either by choosing **File/Exit** or by opening another Plotter file with **File/Open**) that file will be saved.

You can merge a saved file with the current file.

To merge a saved file:

- 1 Choose **File/Merge in** (or press Acorn-M).

A standard Pocket Book file dialogue box is displayed allowing you to select the file to be merged:



- 2 Use the left and right arrows to choose the file that you want to merge, and press Enter.

The graphs and functions in the saved file will be added to those already displayed.

**Note:** A file containing inequality graphs (see *Inequality graphs* on page 13) can only be added to other inequality graphs. A file containing Cartesian, polar and parametric graphs can only be added to other Cartesian polar and parametric graphs. If you try and merge a file containing graphs of the wrong type, a warning is displayed.

## Using Plotter to solve a problem

Here's a short example that shows you how to use Plotter to solve a mathematical problem.

### Problem

Suppose you want to find out at what angle to throw a ball so that it hits a target a given distance away. Assuming that the ball's initial velocity is  $6\text{ms}^{-1}$ , and that the ball is initially at the same height as the target, at what angle do you have to throw the ball to hit a target 3m away?

### Solution

Use Plotter to show the trajectory of the ball for different initial angles.

The general equations of motion for a ball being thrown (neglecting air resistance) are

$$\begin{aligned}x &= u \cos(a)n \\ y &= u \sin(a)n - 0.5gn^2\end{aligned}$$

In parametric form, this becomes

$$u \cos(a)n, u \sin(a)n - 0.5gn^2$$

where

$u$  = initial velocity ( $6\text{ms}^{-1}$ )

$a$  = angle at which ball is initially thrown ( $0^\circ$  is horizontal)

$n$  = time (the independent variable in this case)

$g$  = acceleration due to gravity ( $9.81\text{ms}^{-2}$ ).

Now we can rewrite the equation, filling in the values we know:

$$6 * \cos(a) * n, 6 * \sin(a) * n - 0.5 * 9.81 * n^2$$

$a$  is the angle we're trying to find. We'll plot a family of curves using different values for  $a$ , to find the right value.

- 1 Press Acorn-N to start a new plotter file. Type in a name (e.g. Target) and press Enter:

|            |          |
|------------|----------|
| New file   |          |
| File: Name | Target   |
| Disk       | Internal |

- 2 Make sure you're in Wide mode and Degrees mode.
- 3 Set up appropriate ranges:  
Press Acorn-R and set the x and y ranges as follows:

|               |   |
|---------------|---|
| Display range |   |
| x min         | 0 |
| x max         | 6 |
| y min         | 0 |
| y max         | 2 |

Press Acorn-U and set the range for n as follows:

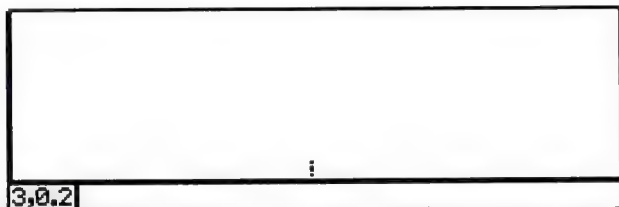
|              |     |
|--------------|-----|
| Other ranges |     |
| n min        | 0   |
| n max        | 2   |
| t min        | 0   |
| t max        | 360 |

(n corresponds to time, and will go from zero to 2s.)

- 4 Enter the following points to mark the target

3,0.05 3,0.1 3,0.15 3,0.2

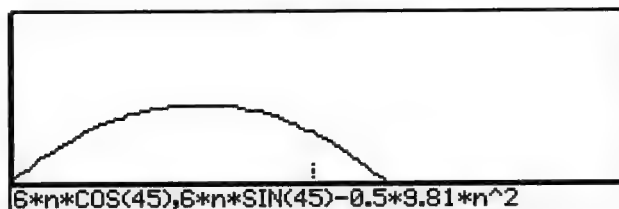
This gives a column, with the target at the bottom:



- 5 Enter the following function, with your first guess for a as 45°:

$6*n*\cos(45), 6*n*\sin(45)-0.5*9.81*n^2$

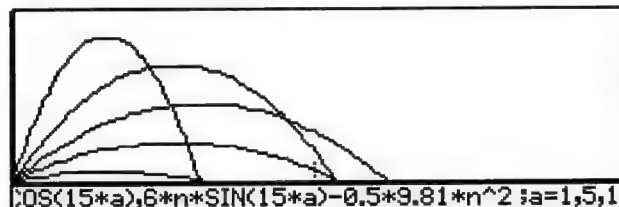
Here's what the trajectory looks like:



- 6 A bit too far! Re-enter the equation with different angles until you hit the target (the correct angle is between 27° and 28°).

You can also have a family of parametric equations. Try this:

$6*n*\cos(15*a), 6*n*\sin(15*a)-0.5*9.81*n^2 ; a=1,5,1$



This illustrates that, under our ideal conditions (i.e. no air resistance) a projectile should be launched at 45 degrees to cover the furthest distance. Also, there are two angles at which you can throw the ball to hit some targets at less than the maximum range.

## Operators and functions

This section lists all the functions and operators you can include in your expressions. *Operator precedence* on page 33 explains the order in which functions and operators are evaluated in an expression.

### Trigonometric functions

|                   |                                   |
|-------------------|-----------------------------------|
| $\sin(x)$         | sine of $x$                       |
| $\cos(x)$         | cosine of $x$                     |
| $\tan(x)$         | tangent of $x$                    |
| $\text{asin}(x)$  | arc sine of $x$                   |
| $\text{acos}(x)$  | arc cosine of $x$                 |
| $\text{atan}(x)$  | arc tangent of $x$                |
| $\sinh(x)$        | hyperbolic sine of $x$            |
| $\cosh(x)$        | hyperbolic cosine of $x$          |
| $\tanh(x)$        | hyperbolic tangent of $x$         |
| $\text{asinh}(x)$ | inverse hyperbolic sine of $x$    |
| $\text{acosh}(x)$ | inverse hyperbolic cosine of $x$  |
| $\text{atanh}(x)$ | inverse hyperbolic tangent of $x$ |

**Note:** when expressing powers in trigonometrical functions, you need to enter functions as follows:

| Function    | Enter this                  |
|-------------|-----------------------------|
| $\sin^2(x)$ | $\sin(x)^2$ or $\sin(x)**2$ |
| $\sin(x^2)$ | $\sin(x^2)$ or $\sin(x**2)$ |

### Logarithmic functions

|           |  |
|-----------|--|
| $\ln(x)$  | natural logarithm of $x$ ( $\log_e x$ )    |
| $\exp(x)$ | $e$ to the power of $x$ ( $e^x$ )          |
| $\log(x)$ | base 10 logarithm of $x$ ( $\log_{10} x$ ) |

### Conversion functions

|                 |  |
|-----------------|--|
| $\text{rad}(x)$ | angle in radians for an angle of $x$ degrees |
| $\text{deg}(x)$ | angle in degrees for an angle of $x$ radians |

### Other mathematical functions

|        |                     |
|--------|---------------------|
| abs(x) | absolute value of x |
| sqr(x) | square root of x    |

### Constants

|   |                                      |
|---|--------------------------------------|
| e | arithmetic constant e (2.71828...)   |
| p | arithmetic constant pi (3.141592...) |

**Note:** You can use p as a constant in functions, though you can't use when setting the ranges for n, t, x or y.

### Operators

|    |  |
|----|--|
| ** | raise to the power ( $x^{**2}$ means $x^2$ ) |
| ^  | raise to the power ( $x^2$ means $x^2$ )     |
| *  | multiplication                               |
| /  | division                                     |
| +  | addition                                     |
| -  | subtraction                                  |

**Note:** Plotter can understand implicit multiplication in a function (it will deprecate the multiplication sign). If you type  $y=2\sin 3x$ , Plotter will enter  $y=2*\text{SIN}(3*x)$  automatically. However, you must place numeric constants before variables for this to work (so,  $y=2\sin x3$  **won't** work).

### Operator precedence

Plotter will evaluate an expression according to the following rules of precedence:

- 1 Any bracketed expressions.
- 2 Functions.
- 3 Negation (i.e. -5).
- 4 Powers (\*\*, ^).
- 5 Multiplication and division.
- 6 Addition and subtraction.

The value of the expression  $2+3*5$  is 17, as multiplication is a higher precedence operation than addition. To have Plotter evaluate the addition first, it has to be surrounded by brackets. The value of  $(2+3)*5$  is therefore 25.

**Note 1:** If an expression contains operators of equal precedence, they are evaluated from left to right.

**Note 2:** Take care when using the minus sign ( $-$ ) in functions. The high precedence of the unary minus can lead to confusion. For example:

$y=1-x^2$  is **not** the same as  $y=-x^2+1$   
the latter evaluates to  $y=(-x)^2+1$ .

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